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Modelling to reconstruct recent wind erosion history of fields in eastern England.

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Introduction

Wind erosion seriously damages crops, jeopardises sustainability and creates dust that is a significant air pollutant in many parts of northwestern Europe. In East Anglia, UK a recent survey showed that farmers expect moderate damage to crops from wind erosion once every three or four years and severe damage once in ten years. Moreover, off-site costs are probably many times those of the on-site costs, based on experience in the USA (Piper 1989). Despite considerable anecdotal evidence there is a dearth of quantitative evidence to support wind erosion and deposition rates (soil flux). This is probably because aeolian activity is dependent on the spatial and temporal variation of the erodibility (Zobeck, 1991) and erosivity conditions. This complexity renders all but the longest and spatially intensive monitoring campaigns unrepresentative of the wind erosion pattern. The selectivity of aeolian processes removes the smaller size fractions which can be considerably enriched in soil nutrients (Zobeck and Fryrear, 1986). However, the affect of this may not be apparent because net soil nutrient loss is small as a consequence of more intensive use of fertilisers and slurries sprayed onto and injected into the soil. Thus, in the U.K., the affect of soil loss by wind on agricultural production is not well documented or understood.

The study utilises an accumulation of soil in a boundary adjacent to a field to validate a model of wind erosion. The study field is located near Thetford in East Anglia, U.K. It typically undergoes a three-year crop rotation of sugar beet, winter wheat and carrots. The easterly end of the field has a large (ca. 1 m) accumulation of soil which began forming in the mid 1950s shortly after a fence was constructed forming a boundary to the easterly end of the field. It is postulated that historical wind erosion events produced the accumulation of aeolian material and recorded its intensity and the type of material removed. The aim here is to construct a model to predict the concentration of nutrients in eroded material under different conditions (plough depths, erosion rates, enrichment ratio and soil nutrient content). Variations in the nutrient content of the dated wind blown accumulation can then be used to examine the impact of historical wind erosion on the field. Further, as historical land use information is available, the impact of different crop types on erosion can be determined.

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Methods

Samples were obtained from the soil accumulation in order to verify the output from the model. A pit was dug in the accumulation and a monolith was removed and sampled every 2 cm along its length. All samples were measured for pH to indicate the redox soil status and mineral magnetic susceptibility which was intended to measure the enhanced levels of secondary ferrimagnetic minerals (e.g. haematite) in the upper soil horizons (Mullins, 1977). Fewer samples were measured for soil chemical properties including total nitrogen (N), available phosphorous (Olsen's P) and exchangeable potassium (K) as indicators of the soil nutrient status.

The Model

For each year since 1954 the model predicts the concentration of P in the accumulation of wind blown material (Equation 1, 2). Phosphorus was chosen initially because it is relatively immobile in the sediment and is a key plant nutrient. Various outputs from the model were plotted against the actual P concentration from the dated profile obtained from the wind blown accumulation. The model accounts for the mixing of subsurface material deficient in P into surface soil after ploughing and the lowering of the soil surface through erosion. The model used a nutrient enrichment factor for the eroded material of two times (based on empirical data from the study site) and assumes there is a small annual accumulation of P due to the excess of artificial inputs over and above plant uptake.

The P concentration in the wind blown material was predicted using the following:

$$P_{surf}^{\ t} = [(D/P) * P_{sub}^{t}] + (P\text{-}D/P_{surf}^{\ t\text{-}1}) * (P_{surf}^{\ t\text{-}1} + F) \qquad \text{Equation 1}$$

Where:
$P_{surf}^{\ t}$ is the predicted P concentration at the soil surface (integrated through the ploughed depth)
$P_{surf}^{\ t-1}$ is the previous years P concentration at the soil surface
D is the depth of soil loss
P is the plough depth
P_{sub}^{t} is the subsurface (below plough depth) P concentration
F is the change in soil surface P concentration after fertiliser additions and plant uptake at the end of the year

And the predicted concentration in the eroded material is:

$$\text{Predicted P concentration in eroded material} = P_{surf}^{\ t} * ER \qquad \text{Equation 2}$$

Where ER is the enrichment ratio of the eroded material to the soil surface concentration.

Discussion

Initial findings suggest that inter annual concentrations of wind blown nutrient content can be predicted using a simple model accounting for mixing in the plough layer and enrichment. It is clear that there have been significant historical losses of P as a result of wind erosion. In this sandy, nutrient deficient soil, fertiliser inputs are increasingly necessary to maintain soil fertility.

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